

RESPONSE CHARACTERISTICS OF VARIOUS SIDE IMPACT DUMMIES

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ABSTRACT

Different side impact dummies and procedures are currently used for the US and Europe/Japan. To harmonize the side impact dummy, WorldSID development was initiated under ISO in 1997. Also, ES-2, an improved version of Eurosid-1, was introduced after SID-IIs, the small side impact dummy.

Side impact dummies are designed and developed based on the ISO TR9790 requirement to provide good biofidelity rating. Even using the same ISO requirement, the existing dummies have different designs and different performances.

Understanding the response characteristics of dummies is important for vehicle development. In this study, response characteristics are studied under the various impact conditions for available side impact dummies. Comparisons between the different dummies in same conditions were made understand different characteristics of each side impact dummy. Full vehicle tests and sled tests are conducted and results are evaluated using DOE (Design of Experiment) method.

SIDE IMPACT DUMMIES

It has been already well known from other research reports that current available side impact dummies have different designs, instrumentations, injury criterion, and structural configurations. In this study, the following four dummies; SID, EUROSID-1, ES-2 and SID-IIs, were evaluated. Explanations for each dummy were summarized below.

SID

SID is regulated dummy in FMVSS214, dynamic side impact protection, in the United States. SID-H3, SID

with Hybrid III head and neck, was used in this study. Acceleration based injury criteria, TTI (Thoracic Trauma Index), was used for thoracic injury, which came from long historical studies in the United States, in this dummy. SID does not have a monitoring capability for abdomen injury.

EUROSID-1

EUROSID-1 is regulated in Europe and Japan. Thorax injury criteria is measured by rib deflection. Major concerns were reported that “rib binding” or “back plate loading” made the measurement results smaller in some impact conditions.

ES-2

ES-2 was proposed for a research dummy as improved version of EUROSID-1. Various evaluations are now being conducted to confirm possibility to regulate in the United States or Europe.

SID-IIs

SID-IIs is the only one small-size (5th female) dummy among available side impact dummies. This dummy is more biofidelic than other mid-size (50th male) dummies as seen in **Table 1** below. SID-IIs is still under developments and to be upgraded to get better durability. SID-IIs of the level B was used in this study.

Table 1.
Biofidelity comparison on ISO/TR9790

Dummy		Rating
SID (-H3)	50 th male	2.3
EUROSID-1	50 th male	4.7
ES-2	50 th male	4.6
SID-IIs	5 th female	7.2

IIHS (Insurance Institute for Highway Safety) had

announced to use SID-IIIs for its new side impact assessment test which simulated small occupants protection in the SUV to vehicle side impact. The first series of evaluation had already been conducted in November 2002.

DUMMY RESPONSE EVALUATION IN SLED TEST

The response characteristics of each side impact dummy were evaluated in HYGE sled. Main purpose of this series of tests was to make the dummy characteristics be able to explain by using some kind of parameters.

Test Method

Simulated interior was set on the HYGE sled. The different trim layout and stiffness were used as parameters to understand the response characteristics of each dummy under different dynamic loading condition. The main effective parameters were chosen as shown in **Figure 1** and **Table 2**. And, each parameter was leveling appropriately as shown in **Table 3**. According to this method, called DOE, the results of test were able to be evaluated statistically.

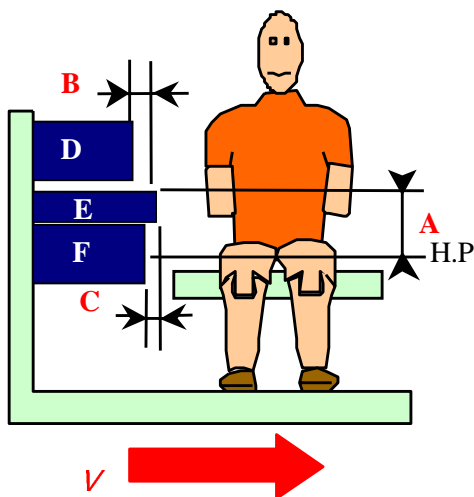


Figure 1. HYGE Sled Overview.

Table 2.

Control parameters for sled tests

A	Armrest Height
B	Gap between Thorax and Abdomen PAD
C	Gap between Abdomen and Pelvis PAD
D	Thorax PAD Stiffness
E	Abdomen PAD Stiffness
F	Pelvis PAD Stiffness

Table 3.

Test parameter matrix

Level		1	2	3
Parameter				
Control Parameter	A [mm]	Low	Mid	High
	B [mm]	Small	Mid	Large
	C [mm]	Small	Mid	Large
	D [Pa]	Soft	Mid	Hard
	E [Pa]	Soft	Mid	Hard
	F [Pa]	Soft	Mid	Hard

Injury Criteria

Each dummy adopted different injury criterion. To evaluate performance equally, the measurements were normalized by regulated limits for each dummy.

For thoracic injury, TTI was used for SID-H3 and RDC (Rib Deflection Criteria) was used for EUROSID-1, ES-2 and SID-IIIs. For abdominal injury, APF (Abdominal Peak Force) was used for EUROSID-1 and ES-2, RDC (Rib Deflection Criteria for abdomen) was used for SID-IIIs. For pelvic injury, in spite of using PSPF (Pubic Symphysis Peak Force) for EUROSID-1, ES-2 and SID-IIIs, pelvic G (acceleration) was used to compare directly for all dummies.

Table 4 shows evaluation criterion in this sled tests. The values inside “[]” are for normalizing, which are based on each regulation. The columns of SID-H3 abdomen and EUROSID-1 pelvis are blank. Because SID-H3 doesn’t have instrumentation for abdomen, EUROSID-1 was missed pelvis G data in some tests.

Table 4.
Evaluating Injury Criteria

	SID-H3	EUROSID-1	ES-2	SID-IIs
Thorax	TTI [85]	RDC [42mm]	RDC [42mm]	RDC [34mm]
Abdomen	----	APF [2.5kN]	APF [2.5kN]	RDC [32mm]
Pelvis	G	----	G	G

* []: Normalizing Values

Discussion

Thorax: **Figure 2** shows “The effect plot” for Thorax with selected A to F. The vertical axis shows normalized injury criteria and the horizontal axis shows parameters and their levels.

EUROSID-1 and ES-2 responses relative to parameters A to F are almost the same. B (the gap between thorax and abdomen PAD) and D (thorax pad stiffness) are especially sensitive to these dummies. For example, if B gets larger, thorax injury get reduced. The responses of between EUROSID-1 / ES-2 and SID-IIs shows similar tendency.

SID-H3 shows different responses from other dummies. It has high sensitivity for D (thorax PAD stiffness), but not much influenced by other parameters.

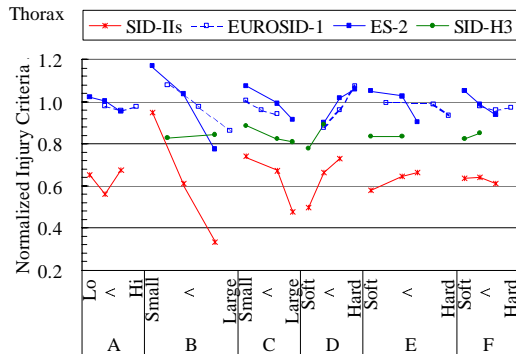


Figure 2. Effect plot means responses of Thorax Region.

Abdomen: **Figure 3** shows the responses of the abdomen except SID-H3 dummy. The constitution of graph follows **Figure 2**. Dummy response for parameter A (the height of abdomen PAD), SID-IIs shows opposite trend to that of EUROSID-1 and ES-2. This is assumed that the lower seating height of SID-IIs caused the different loading mode from mid-size dummies.

SID-IIs, EUROSID-1 and ES-2 has the same tendency to B (the gap between thorax and abdomen PAD) and E (the abdomen PAD stiffness).

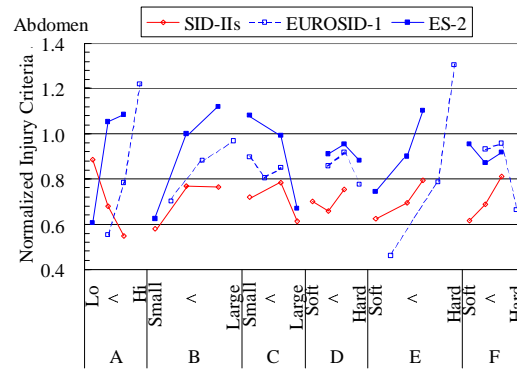


Figure 3. Effect plot means responses of Abdomen Region.

Pelvis: **Figure 4** shows the pelvis responses of SID-IIs, ES-2 and SID-H3. To evaluate the responses of pelvis region, the pelvis G was used. EUROSID-1 was excluded in this evaluation as mentioned above.

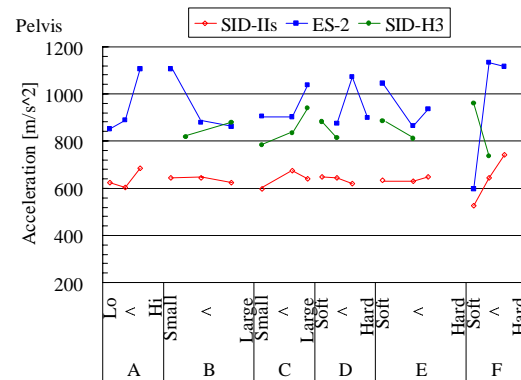


Figure 4. Effect Plot means responses of Pelvis Region.

The pelvis G is sensitive for F (pelvis PAD stiffness). ES-2 has unique response for B (the gap between thorax and abdomen PAD). If B gets larger, the injury level of pelvis gets lower. This is assumed that the harder abdomen construction of ES-2 propagates the force well.

Summary of Sled Tests

Dummies with different structure designs tend to show different response characteristics due to the different load path in the body.

The dummy size difference tends to show different response characteristics by chosen parameters. And, it is assumed that size difference causes different loading mode.

FULL-SCALE TESTS

The full-scale tests were conducted in three test procedures. An overview of this test program is given in **Table 5**. The purpose of this study was to evaluate the each dummy performance in the same test condition.

Table 5.
Overview of full-scale tests

	Test Procedure	Dummy
1	SINCAP(FMVSS214) @54.7km/h	SID-H3 vs. ES-2
2	EuroNCAP(EC54) @50km/h	EUROSID-1 vs. ES-2
3	IIHS SUV side impact @50km/h crabbed	SID-IIs vs. EUROSID-1

SID-H3 vs. ES-2 in SINCAP

To compare SID-H3 with ES-2, the full-scale test was performed in SINCAP procedure. Since each dummy had unique injury criteria for thorax, two methods were used to evaluate the results.

One method was evaluation by TTI in **Table 6**. The other method is comparison with injury criteria normalized by regulatory limits as shown in **Table 7**.

Table 6.
Evaluating injury criteria following SINCAP

	SID-H3	ES-2
Thorax (TTI)	Rib UPR G	
	Rib LWR G	
	Spine LWR G	
Pelvis	Pelvis G	

Table 7.
Evaluating injury criteria in each regulation

	SID-H3 (SINCAP)	ES-2 (EuroNCAP)
Thorax	TTI [85]	RDC [42mm]
Abdomen		APF [2.5kN]
Pelvis	Pelvis G [130]	PSPF [6kN]

* []: Normalizing Values

Results: **Figure 5** is the comparison of TTI. The vertical axis shows G and the lateral axis shows injury index of each seating position. It was revealed that two dummies had quite similar injury criterion in both TTI and pelvis G within both seating positions.

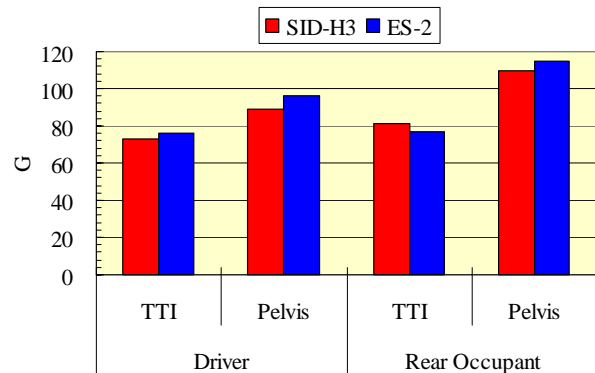


Figure 5. Test results for comparison of SID-H3 and ES-2 in SINCAP criteria.

Figure 6 shows the comparison with injury criterion normalized by each regulatory limit. TTI of SID-H3 and APF of ES-2 were described dot line as reference in **Figure 6**.

It is observed that injury criteria in the driver are almost same in both dummies, however injury levels in the rear occupant are lower for the thorax and higher for the pelvis with ES-2 than those of SID-H3. This could be attributed that the rear door intruded obliquely into the occupant.

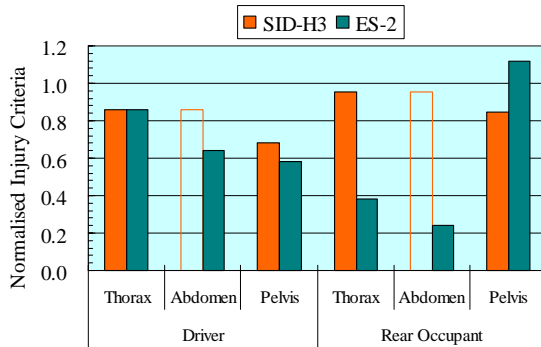


Figure 6. Test Results for comparison of SID-IIs in SINCAP and ES-2 in EuroNCAP criteria.

Discussion: Figure 7 shows that typical relationship on the driver Rib LWR G and RDC LWR of ES-2. On the other hand, Figure 8 shows that there was very small RDC LWR in spite of Rib LWR G level on the rear occupant. This data assumed that the direction of impact was different from that of rib deflection.

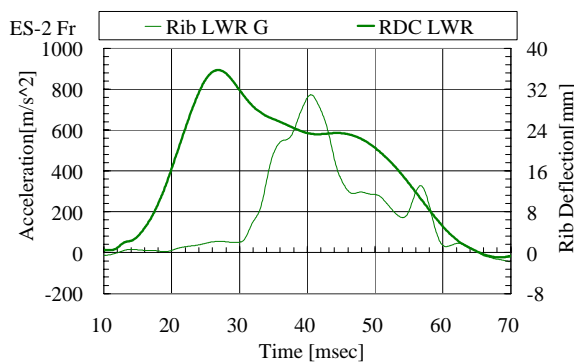


Figure 7. Lower rib G and deflection of ES-2 on driver seat.

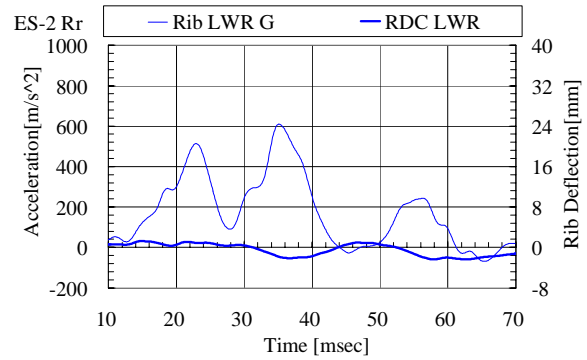


Figure 8. Lower rib G and deflection of ES-2 on rear occupant seat.

Figure 9 and Figure 10 show the typical relation between Pelvis G and PSPF of ES-2 on the driver and rear passenger. The higher PSPF of ES-2 on rear occupant assumed to cause loading into the femur.

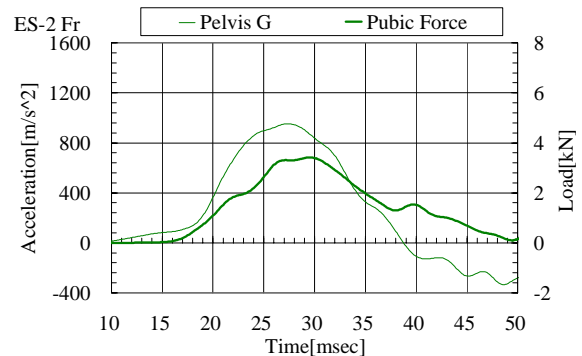


Figure 9. Pelvis G and Pubic Force of ES-2 on driver seat.

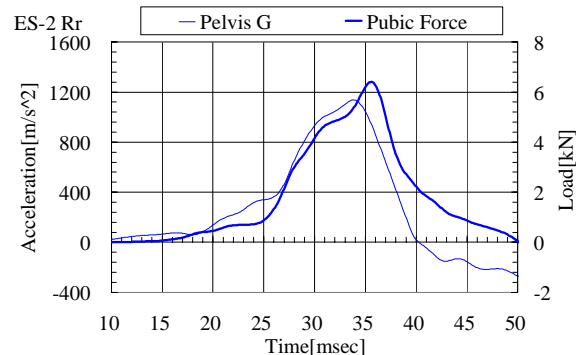


Figure 10. Pelvis G and Pubic Force of ES-2 on Rear Passenger seat.

EUROSID-1 vs. ES-2 in EuroNCAP

The design intention of ES-2 is to solve major concerns, in particular “flat-top” rib deflection and “B/P (back plate) loading” into the spine. The response characteristics between EUROSID-1 and ES-2 had been studied and resulted as almost same through sled tests. To compare the performance difference between EUROSID-1 and ES-2, full-scale tests were performed in EuroNCAP procedure.

Results: Figure 11 shows the results with normalized injury criteria. RDC of ES-2 measured much higher than that of EUROSID-1 in spite of similar values for HPC, APF and PSPF. B/P force was remaining high as same level as EUROSID-1.

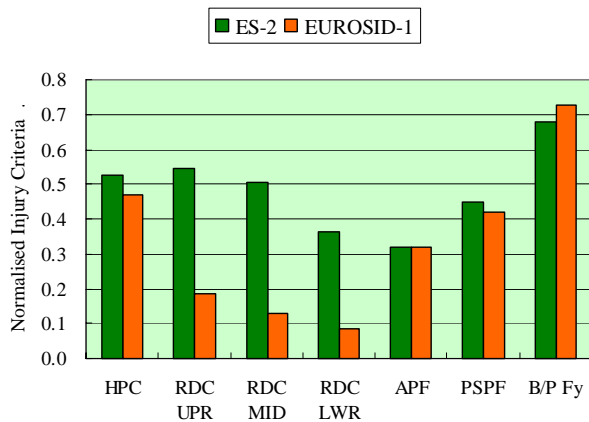


Figure 11. Test results for comparison of ES-1 and ES-2 on EEC criteria.

Discussion: ES-2 has a newly designed rib modules which intend to solve “flat top” issue by eliminating rib binding. And, it has a new B/P which intend to eliminate the unsuitable load path to the spine.

Despite of reshaping, B/P force was remaining still high as seen Figure 12. The smaller B/P had resulted just short time delay on loading. Considering these results, the increase of the RDC was caused by resolving “flat top”. And, its issue was solved by the elimination of rib binding.

Figure 13 and Figure 14 shows the comparison of rib deflection and that “flat-top” was eliminated.

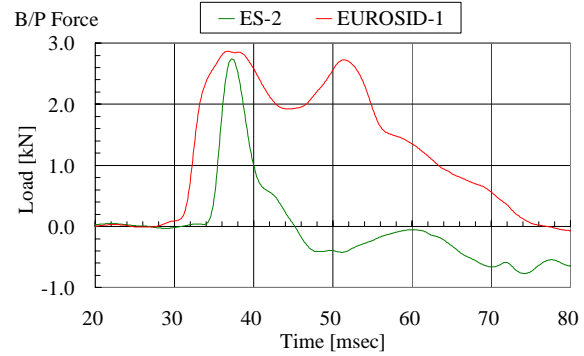


Figure 12 Back Plate Force.

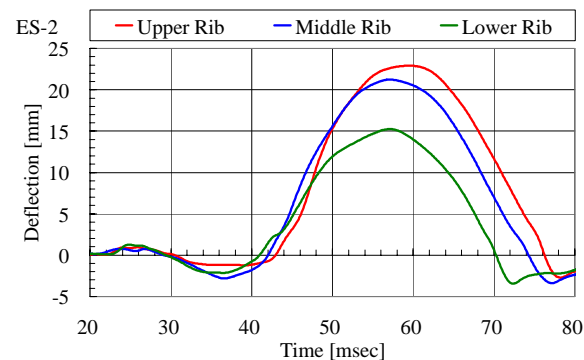


Figure 13. Rib Deflection of ES-2.

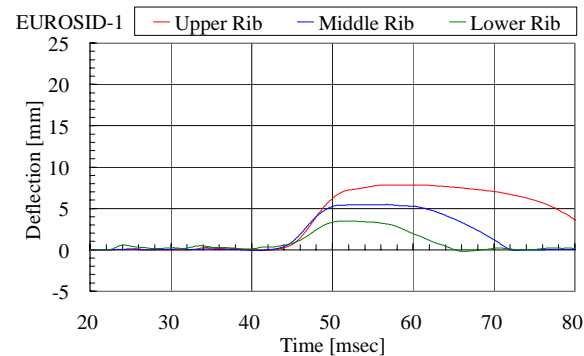


Figure 14. Rib Deflection of EUROSID-1.

SID-IIs vs. EUROSID-1 in SUV Side Impact

The purpose of this test was to evaluate the performance of different size dummies in same condition. This full-scale side impact tests were performed in IIHS side impact procedure with SID-IIs and EUROSID-1. The MDB striking condition was selected crabbed to match the early stage of IIHS study.

Results:

Figure 15 shows the comparison of the each injury criteria. The criterion are normalized by regulatory limits and IARV. SID-II's injury criterion tends to show higher than those of ES-2 due to the vulnerable properties of small female.

High HIC was observed in SID-II's by the direct contact with MDB surface, which caused from SID-II's lower seating height.

SID-II's abdomen injury showed greater increase from EUROSID-1 more than thorax, which was assumed by the structural difference of abdomen between EUROSID-1 and SID-II's.

Only PSPF of SID-II's was lower than EUROSID-1.

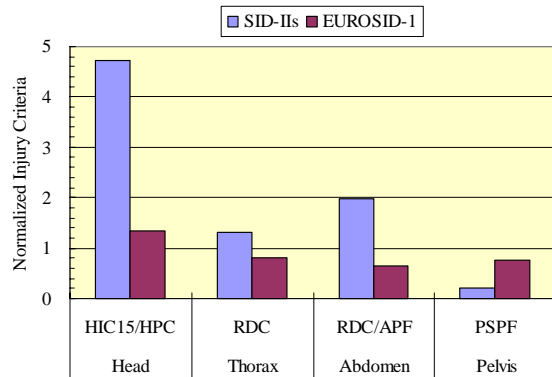


Figure. 15 Test Results for comparison of SID-II's and EUROSID-1.

Discussion:

Figure 16 is the comparison between pubic force and pelvis G of SID-II's. The same comparison of ES-2 is shown in **Figure 17**.

As shown in **Figure 16**, the pubic force data is negative during the impact. The validity of this data is suspect.

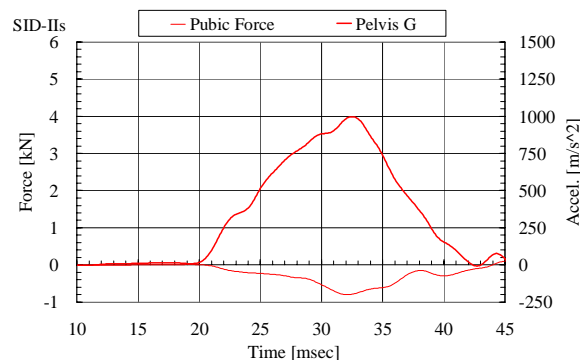


Figure 16. Pubic Force and Pelvis G of SID-II's.

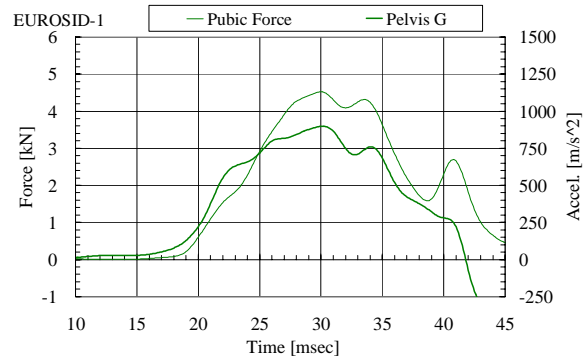


Figure 17. Pubic Force and Pelvis G of EUROSID-1.

CONCLUSION

To summarize these studies, following conclusions are made;

As different response characteristics are observed in dummies with different structure designs and instrumentation, using one design with highly biofidelic dummy and adequate injury criterion is extremely beneficial to evaluate reasonable occupant protection performance.

From this reason, the delivery of WorldSID is highly anticipated and further research of response characteristics of side impact dummy would be reported after the delivery.

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